

~ 32 ~

**CLAIMS**

1. A probe (22) for use in an atomic force microscope or for nanolithography, the probe comprising a force sensing member (3) connected to a probe tip (4) having a tip radius of 100nm or less characterised in that the probe includes a biasing element (24, 50) which is responsive to a substantially deflection-independent externally applied force for urging either or both of the probe tip (4) and a sample towards each other.
2. A probe (22) as claimed in claim 1 characterised in that the biasing element comprises a magnetic element (24) responsive to an externally applied magnetic force.
3. A probe as claimed in claim 2 characterised in that the magnetic element (24) is mounted on the force sensing member (3) adjacent the tip (4).
4. A probe (22) as claimed in claim 1 characterised in that the biasing element comprises an electrically conductive member (50) adapted for connection to one terminal of a power supply (60) for applying a voltage potential between the probe (22) and the sample.
5. A probe (22) as claimed in any one of the preceding claims characterised in that the biasing element is provided adjacent the probe tip (4).
6. A probe (22) for use in an atomic force microscope or for nanolithography, the probe comprising a force sensing member (3) connected to a probe tip (4) having a tip radius of 100nm or less characterised in that the probe is adapted such that, when subject to an externally applied force, a biasing force urges either or both of the

~ 33 ~

probe tip (4) and a sample towards each other with magnitude greater than a restoring force arising from a displacement of the probe tip as it probes the sample.

7. A probe (22) as claimed in any one of the preceding claims characterised in that the force sensing member (3) has a low quality factor for one or more vibrating modes of the force sensing member (3).
8. A probe (22) as claimed in claim 7 characterised by the force sensing member (3) including a damping element (22c) adapted to dissipate energy that would otherwise be mechanically stored in the force sensing element through excitation of one or more oscillatory modes.
9. A probe (22) as claimed in claim 8 characterised in that the damping element (22c) comprises a coating of a mechanical-energy absorbing material on at least one side of the force sensing element (3).
10. A probe (22) according to claim 9 characterised in that the energy-absorbing material is a polymer film.
11. A probe (22) according to claim 10 characterised in that the polymer film is formed of a copolymer with majority component that is an amorphous rubber and a minority crystalline or glassy component.
12. A probe (22) according to claims 10 or 11 characterised in that the force sensing member (3) is coated with polymer by solution casting.
13. A probe (22) according to claim 8 characterised in that the damping element (22c) is provided by a region (Region 3) of the force sensing member (3) having controlled spring constant.
14. An atomic force microscope (10) for imaging a sample in accordance

~ 34 ~

with an interaction force between the sample and a probe (22), the microscope (10) comprising

driving means (16, 18, 20, 70) arranged to provide relative scanning motion between the probe (22) and the sample surface and capable of bringing the sample and probe (22) into close proximity, sufficient for a detectable interaction to be established between them; and

a probe detection mechanism (28) arranged to measure deflection and / or displacement of the probe (22);

characterised in that, the microscope (10) includes the probe (22) of any one of claims 1 to 13.

15. An atomic force microscope as claimed in claim 14 characterised by further comprising a resonant oscillator mechanically coupled to either the probe (22) or a sample stage for causing relative oscillatory movement between the probe (22) and the sample.

16. An atomic force microscope (10) for imaging a sample in accordance with an interaction force between the sample and a probe (22), the microscope (10) comprising

driving means (16, 18, 20, 70) arranged to provide relative scanning motion between the probe (22) and the sample surface and capable of bringing the sample and probe (22) into close proximity, sufficient for a detectable interaction to be established between them; and

a probe detection mechanism (28) arranged to measure deflection and / or displacement of the probe (22);

characterised in that, the microscope (10) includes force ( $F_{\text{direct}}$ )

~ 35 ~

generating means (24, 26; 50, 60) arranged such that, in operation, a force ( $F_{\text{direct}}$ ) is applied to either or both of the sample and the probe (22) or between the sample and the probe (22), the force ( $F_{\text{direct}}$ ) being directed so as to urge the probe (22) towards the sample or *vice versa*.

17. A microscope according to claim 16 characterised in that the force ( $F_{\text{direct}}$ ) has a magnitude that is substantially independent of the degree of deflection of the probe (22).
18. A microscope according to claim 17 characterised in that the probe (22) has spring constant  $k$  and the probe (22) properties and the applied force ( $F_{\text{direct}}$ ) are selected such that, at least within a predetermined timescale, the applied force ( $F_{\text{direct}}$ ) is greater than the restoring force  $kx$  provided by a deflection  $x$  of the probe (22) as it scans the surface of the sample.
19. A microscope according to claim 18 characterised in that the probe (22) has spring constant  $k$  that is less than  $1 \text{ Nm}^{-1}$ .
20. A microscope according to any one of claims 16 to 19 characterised in that the force ( $F_{\text{direct}}$ ) generating means comprises a magnet (26) and a magnetic element (24) incorporated in the probe (22).
21. A microscope according to any one of claims 16 to 19 characterised in that the force ( $F_{\text{direct}}$ ) generating means comprises means (50, 60) for applying an attractive biasing voltage between the probe tip (4) and the sample.
22. A microscope according to any claim 16 characterised in that the force ( $F_{\text{direct}}$ ) generating means comprises a sample environment which encourages the formation of a capillary neck between the probe (22) and the sample, the capillary neck providing said applied force ( $F_{\text{direct}}$ ).

~ 36 ~

23. A microscope according to claim 22 characterised in that the force ( $F_{\text{direct}}$ ) generating means further comprises a hydrophilic surface on said probe (22).
24. A microscope according to any one of claims 16 to 23 characterised in that the probe (22) has a low quality factor.
25. A microscope according to claim 24 characterised by further comprising means (80) for immersing the probe (22) and sample in a liquid during operation of the microscope.
26. A microscope according to claim 24 characterised in that the force sensing element (3) of the probe (22) includes a damping element (22c) adapted to dissipate energy that would otherwise be mechanically stored in the force sensing element (3) through excitation of one or more oscillatory modes.
27. A microscope according to claim 26 characterised in that the damping element comprises a coating of a polymeric material (22c) on at least one side of the force sensing element (3).
28. An atomic force microscope as claimed in any one of claims 16 to 27 characterised by further comprising a resonant oscillator mechanically coupled to either the probe (22) or a sample stage for causing relative oscillatory movement between the probe (22) and the sample.
29. A method of collecting image data from a scan area of a sample with nanometric features wherein the method comprises the steps of:-
- (a) moving a probe (22) having a force sensing element (3) with a tip (4) having a tip radius of 100nm or less into close proximity with a sample in order to allow an interaction force to be established between probe (22) and sample;

~ 37 ~

- (b) causing a substantially deflection-independent force ( $F_{\text{direct}}$ ) to be established between sample and probe (22) such that the probe (22) is urged to move towards the sample (14) or *vice versa*;
  - (c) scanning either the probe (22) across the surface of the sample or the sample beneath the probe (22) whilst providing a relative motion between the probe (22) and sample surface such that an arrangement of scan lines covers the scan area;
  - (d) measuring deflection and / or displacement of the probe (22); and
  - (e) processing measurements taken at step (d) in order to extract information relating to the nanometric structure of the sample.
30. A method as claimed in claim 29 characterised by further comprising during step (c) dissipating energy which otherwise would be stored in the force sensing element (3) through excitation of oscillatory modes.
31. A method as claimed in either claims 29 or 30 characterised in that the relative motion between the probe (22) and the sample surface under step (c) is provided by a resonant oscillator.
32. A scanning probe microscope (10) for writing information to a sample by means of an interaction between the sample and an AFM cantilever probe (22), the microscope comprising
- driving means (16, 18, 20, 70) arranged to provide relative scanning motion between the probe (22) and the sample surface and capable of bringing the sample and probe (22) into close proximity; and
- a probe writing mechanism arranged to vary intermittently, typically on a timescale shorter than one scan line, the strength of the interaction between the probe and the sample and so to change intermittently a

~ 38 ~

property of the sample surface in the locality of the probe;

characterised in that, the microscope (10) includes force ( $F_{\text{direct}}$ ) generating means (24, 26; 50, 60) arranged such that, in operation, a substantially deflection-independent force ( $F_{\text{direct}}$ ) is applied to either or both of the sample and the probe (22) or between the sample and the probe (22), the force ( $F_{\text{direct}}$ ) being directed so as to urge the probe (22) towards the sample or *vice versa*.

33. A microscope as claimed in claim 32 characterised in that the relative motion between the probe (22) and the sample surface is provided by a resonant oscillator.